An Analysis of A Mobile Platform's In-App Advertising Contract under Agency Pricing for App Sales

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Abstract

We develop a two-sided market model that captures two unique features of the in-app mobile advertising market: the joint structure of the adverting platform and agency pricing for the app sales channel. In the joint structure of the mobile advertising platform, both the platform owner and the app developer jointly control the provisioning of ads compared to the platform owner alone in the traditional advertising platform. We analyze the platform owner's optimal in-app advertising contract that will drive the advertisers and app developer to engage in publishing ads within apps. Our results reveal the market conditions that dictate when the platform owner can profit by raising the app developer's revenue sharing percentage in the in-app advertising contract, and when an app developer can benefit from the growth of the advertiser side of the market. We also investigate the impact of agency pricing for app sales on the platform owner's in-app advertising contract. We show that the advertising revenue-sharing contract fails to coordinate the advertising platform in the presence of agency pricing for app sales, which may lead to higher app prices for app users.

Keywords: mobile platform, two-sided market, advertising contract, agency pricing, revenue sharing

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INTRODUCTION

When Apple first launched its iPhone App Store in July 2008, few in the industry could have anticipated how drastically it would change the software market. After five years of accelerating growth, Apple's App Store is the world's leading mobile app market, having recently reached the 50 billion download milestone (Arthur 2013), a five-fold increase from early 2011 (The Associated Press 2011). Revenue from app sales experienced similar growth, with IHS Inc. reporting that approximately $1.7 billion in revenue (IHS Inc. 2011) was generated from more than 350,000 applications inside the Apple App Store in 2010 (Whitney 2011). Now in 2013, this annual revenue figure stands at about $3.86 billion (Arthur 2013). Following Apple's success, Google, Microsoft and RIM also opened mobile app markets for their own mobile ecosystems. At this point many software developers, ranging from small firms like The Pixelmator Team to traditional giants like Salesforce.com, develop applications that are released, sold and maintained on mobile platforms.

The tremendous success of mobile app markets has created a massive mobile app user base that is alluring to potential advertisers. To develop and benefit from this market, mobile platform owners like Apple have introduced mobile advertising services such as iAd, which integrate advertisements into mobile apps, thus creating opportunities for advertisers to reach mobile app users. To entice mobile app developers to publish ads in their apps, the platform owner passes a portion of the advertising revenue collected from advertisers to the app developer. In this situation the app developer faces the decision we have framed as a key research question in this paper: Is it better to focus on selling apps or selling ads, or can one profitably do both?

The platform owner also faces a problem: having established a healthy and rapidly growing market for app sales, one which has thrived on a set revenue-sharing plan, how can they profitably induce the app developers to shift their focus to advertising revenue as the value of mobile advertising increases?

Some market evidence implies that the answers to those questions might not be straightforward. For platform owners, the revenues from mobile advertising were very modest compared to the billions in app sales revenues. In 2011 iAd only generated $92.4 million in total revenue and the entire US mobile display ads spending was only approximately $513.5 million (eMarketer January 2012). One year later US mobile display ad spending jumped to 4.06 billion and iAd's total revenue increased to approximately $412.7 million (eMarketer December 2012). Yet in mobile app developer online communities like iPhoneDevSDK.com, many developers claim that their total revenues are relatively unchanged after joining the ad services – the benefit of becoming a publisher is not clear to them. What accounts for the flat revenue that the developers complain about? What are the factors that drive growth of advertising revenue, and which factors potentially hinder growth?

To address these questions, we developed a two-sided advertising model with advertisers and app users as the two sides of the market. While the two-sided advertising model has been widely used in previous advertising studies (Anderson and Gabszewicz 2006), we take into account several differences between the mobile advertising platform and traditional media platforms. First, a two-sided market analysis of traditional advertising considers a platform owner, a mass of consumers and a mass of advertisers. The platform owner, such as a television broadcaster, sets the price of advertisement for advertisers and the price of accessing content for consumers (Anderson and Coate 2005). In the context of such traditional media, a single entity controls the provisioning of both the content and advertisements. A key difference in the case of mobile advertising is that the provisioning of the app and the advertisement are not solely controlled by the platform owner, but also by the app developer. On the app user side of the market, it is the developer rather than the platform owner who created the app and decides the app price (iOS Developer Program, Apple Inc 2013a). On the advertiser side of the market, the platform owner sets the ad price but also must induce the app developer to become an ad publisher in order to present ads to the app users (iAd App Network Policy, Apple Inc 2013b). Thus in our model the advertising platform is necessarily more complex, and consists of two distinct entities, the platform owner and the app developer, who together provision both the app and the advertisement. Since the platform owner provides the channel for the developer's app to reach app users, and for ads to reach app users through the developer's app, we hereafter refer to the platform owner as the channel owner.

Another important feature that distinguishes the mobile advertising platform from the traditional one is the use of agency pricing for the app sale. Agency pricing is a mechanism that allows the developer, in our context, to decide the app price. This term originated in the e-book industry, where it involves a retailer that delegates the retail pricing decision to the book publisher (Hao and Fan 2014; Li et al. 2013). In exchange for gaining control of the retail price, the book publisher agrees to a revenue sharing contract with the retailer which splits the total sales revenue based on a contractually fixed percentage (Trachtenberg 2011). Mobile platforms also adopted this agency pricing, for example, the developer sets the price for its iOS app, and shares a fixed percentage (usually 30%) of its app sales revenue with Apple, the channel owner.

By capturing these unique characteristics of the mobile app market in our model, we are able to develop several key insights that address the questions raised above. First we find that when the value of mobile advertising (hereafter ad value) increases, the app developer will focus more and more on publishing advertising, in some cases to the point where the app is given away for free and the app developer focuses entirely on ad revenue. However, the app developer's profit is sensitive to ad value and only increases substantially when the ad value is in a certain range.

Furthermore we find that when market conditions support both app sales and ad publication, the channel owner will adopt one of two distinct strategies. When ad value is relatively low, the channel owner will only provide the minimal amount of incentive required by the app developer to become a publisher and then capture all the profit above that minimal amount. When ad value is relatively high, the channel owner finds it optimal to raise the app developer's ad revenue share, i.e., to subsidize the developer in the advertising channel. We call this between-agent subsidization strategy. This between-agent subsidization in the advertising channel increases the developer's incentive to reduce the app price in the app sales channel, which in turn subsidizes the app users, creating a larger app user base and generating greater advertising profit and greater total profit for both the channel owner and the developer. We find that agency pricing for app sales leads to the channel owner's between-agent subsidization strategy as well as to the app developer's substantial profit growth with increasing ad value. The app developer's pricing right on app sales not only gives the developer market power in the app sales channel, but also benefits him in the advertising channel when the ad value is moderately high.

The unique joint structure of the mobile advertising platform, consisting of the channel owner and the app developer as independent decision makers engaged by an advertising revenue sharing contract, poses an issue of coordination. We use the term coordination in the way it is used in the supply chain literature (Cachon and Lariviere 2005); so our platform is coordinated if the aggregate profit is the same as it would be if the channel owner and app developer were integrated as one. We demonstrate that in the presence of agency pricing for app sales, the advertising revenue sharing contract fails to coordinate the platform, which may lead to higher app prices for app users.

The rest of this paper is organized as follows. After reviewing the relevant literature, we set up a mobile advertising model and analyze both the app developer's and the channel owner's strategies. Then we discuss the underlying factors that drive the formation of these strategies, through illustrating the comparative statics of important market equilibrium outcomes. After that, we investigate the issue of coordination within the platform. Finally, we conclude with theoretical and managerial implications of the paper.

LITERATURE REVIEW

Our paper is related to the economic analysis of traditional advertising markets. In recent years, researchers in economics, marketing and information systems have used two-sided economic models to examine the market dynamics of traditional advertising markets such as newspaper and TV advertising. Anderson and Coate (2005) study advertising provisioning in the broadcasting industry. They show that the equilibrium advertisement level could be either too low or too high in terms of maximizing social welfare, depending on the nuisance cost to viewers. Using a similar two-sided market model framework, Anderson and Gabszewicz (2006) investigate both the short-run and long-run pricing equilibria for the advertising market. Godes et al. (2009) demonstrate that when a media firm's revenue comes from both the content sale channel and the advertising channel, the media firm would focus on the profit from the advertising channel when competition on the content side of the market increases. Bagwell (2007) provides a comprehensive survey of economic analysis of various aspects of advertising, including quality signaling, entry deterrence, and others.

Our paper is also related to research modeling online advertising in the field of information systems, which studies how various aspects of advertising influence a firm's strategy and revenue in its existing business, given that the firm is either an ad publisher or an advertiser. For example, Liu et al. (2012) show that under IT capacity constraints, although advertising may prompt a customer to switch between firms it may not result in a sale for either of the firms in a duopolistic setting. Dellarocas (2012) shows that if advertisers endogenously determine the prices of advertised goods, the pay-per-action pricing mechanism results in price distortion of the advertised goods. Chen and Stallaert (2012) study the impact of behavioral targeting on online publisher's revenue and identify two effects associated with behavioral targeting, the competitive effect and the propensity effect, that determine whether the impact will be positive or negative. Xu et al. (2011) use a game-theoretic model to study the value of an advertising position in price competition. Xu et al. (2012) analyze how the organic (i.e., unpaid) listing affects advertisers' bidding in sponsored search advertising.

There is also a significant literature investigating how a firm should optimally incorporate advertising into its overall monetizing strategy to maximize total profit, which is closely related to the topic of our paper. Tan and Mookerjee (2005) study the issues involved in optimally allocating spending between information technology and advertising in electronic retailing. Kumar and Sethi (2009) demonstrate a publishing firm's hybrid dynamic pricing strategies for web content with two revenue sources – a subscription fee and advertising. Lin et al. (2012) investigate firms' optimal monetizing strategies for advertising under vertically differentiated products in both monopoly and duopoly settings. Zhang and Feng (2011) discover that in the context of search-engine advertising, advertisers may adopt cyclical bid adjustments which can result in a cyclical pattern of the equilibrium bidding prices under certain conditions.

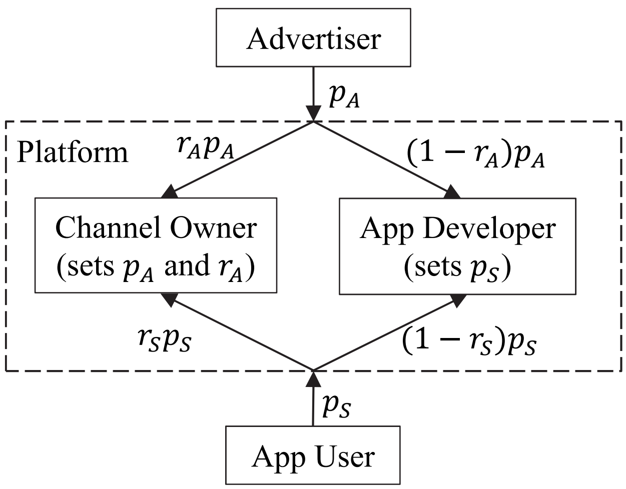
Another strand of online advertising literature investigates the characteristics of different advertising models and discusses a firm's optimal choice among them. Feng and Xie (2012) identify ad performance, demand uncertainty and information as important dimensions that influence the signaling effect of performance-based advertising, and derive the conditions under which the merchant as an advertiser would want to switch to performance-based advertising. Asdemir et al. (2012) examine important factors in two pricing models that influence the preference of advertisers as well as publishers: cost-per-click-through (CPC) and cost-per-thousand-impression (CPM). They identify several major factors including uncertainty concerning the target segment boundaries; the value of advertising to the target segment; the cost of mis-targeting ads to consumers in the non-target segment; and the difference in alignment of incentives of the advertiser and the publisher. Hu et al. (2012) compare the CPC model and the cost-per-action model (CPA) model and discover several critical factors such as uncertainty in the product market, advertisers' risk aversion, and the presence of advertisers with low immediate sales percentages, which affect the publisher's choice between the CPC model and CPA models. Liu and Viswanathan (2012) study the advertising provider's optimal choices among CPM, CPC, CPA and various hybrids and identify the role of information asymmetry in determining the optimal choice.

Our study contributes to the literature in the following ways. First, we develop an extended two-sided market model that captures the unique features of the mobile advertising market. Prior studies in two-sided market analysis of advertising consider the advertising platform as a single entity that controls the provisioning of both the content and the ads. We model the joint structure of the platform, as well as agency pricing for the app sales channel, with two separate entities: a platform owner and an app developer that jointly control the provisioning of apps and ads. Second, we contribute to the online advertising literature in the field of information systems by investigating mobile advertising, a new frontier of internet advertising. Specifically, we analyze the app developer's and the channel owner's optimal strategies under various market conditions. We determine the conditions under which the platform owner can profit by subsidizing the app developer, using a type of between-agent subsidization strategy that is unique to the mobile advertising setting. Third, we show that the advertising revenue-sharing contract fails to coordinate the advertising platform in the presence of agency pricing for app sales. This finding raises a potential issue for policy makers concerning efficiency loss in mobile advertising.

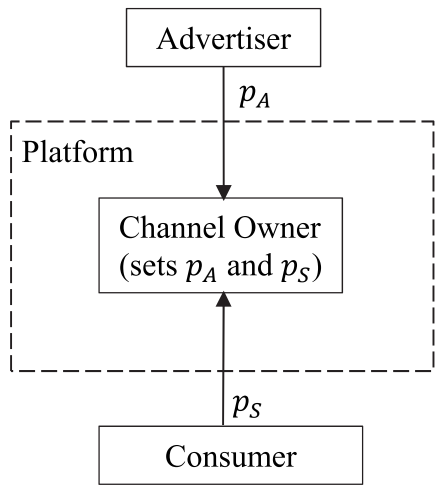
MODEL

In this section, we propose a two-sided market model of mobile advertising which includes a channel owner, a representative app developer, a mass of app users and a mass of advertisers (shown in Figure 1a). On the app user side of the market, following the agency pricing contract, the app developer sets the app price p_S, passing a share of app sales revenue r_S to the channel owner. This is a reflection of current industrial practices, for example, with the iTunes app store for the Apple mobile platform. On the advertiser side of the market, the channel owner makes two decisions in the advertising contract: (i) the ad price p_A charged to the advertiser; and (ii) the channel owner's ad revenue share r_A, as seen for example in the iAd advertising network for the Apple mobile platform. The app developer, if he chooses to become an ad publisher, agrees to this advertising revenue sharing contract and receives the remaining $1 - r_A$ share of the advertising revenue. Figure 1b illustrates the market structure of traditional advertising.

Comparing Figure 1a and Figure 1b reveals the major difference in market structure between mobile advertising and traditional advertising: in traditional advertising the channel owner, for example a TV broadcaster, sets prices for both sides of the market, while in mobile advertising the channel owner, for example Apple Inc., only sets the price for the advertiser side of the market, allowing an independent firm, the app developer, set the price for the app user side of the market.



1a: Mobile Advertising



1b: Traditional Advertising

Figure 1: Market Structure

To model app users, we consider a single representative app and app developer, and take app users to be heterogeneous in their valuation for the app v_S, which is uniformly distributed on $[0, V_S]$. The total size of the app user market is normalized to 1. An app developer that chooses to publish advertising allocates ad space in the app for displaying ads. The allocated in-app ad space can then be filled by the channel owner, with a certain probability, upon request by the app developer. Those in-app ads generate disutility for the app user, which is referred to in the literature as a nuisance cost. On the advertiser side of the market, we use n_A to denote the number of participating advertisers and m to denote the total number of potential advertisers. Following existing literature, we assume that each advertiser produces one advertisement. Then n_A can be interpreted as representing the number of advertisements in the channel owner's ads inventory, i.e., the ad demand. Denote ρ_i as the probability that ad i will be displayed in the ad space upon an arbitrary ad request from the app. The fill rate η, which represents the probability that the in-app ad space will be filled with ads from the ad inventory, is the sum of all ρ_i, i.e., $\eta(n_A) = \sum_{i=1}^{n_A} \rho_i$. The fill rate $\eta(n_A)$ has the following properties: $\eta(0) = 0$, $\eta(m) = 1$, and $\eta(n_A)$ is monotonically non-decreasing in n_A. Therefore, we use $\eta(n_A) = \beta n_A$ as a linear approximation, where β is the slope parameter. Hence, the nuisance cost of advertising is denoted by $\gamma\beta n_A$, where γ is the nuisance cost when the ad space in the app is filled with ads and βn_A is the probability that the ad space will be filled. This modeling approach of the nuisance cost due to advertising is consistent with prior literature (Anderson and Coate 2005). Thus, for app user v_S, the utility for the app, if the app developer chooses to publish advertising, is:

$$u(v_S) = v_S - \gamma\beta n_A - p_S.$$

The corresponding app demand is:

$$n_U = \Pr(u(v_S) \geq 0) = 1 - \frac{\gamma\beta n_A}{V_S} - \frac{p_S}{V_S}.$$

If the app developer decides against advertising in the app, the utility of the app for app user v_S is $u(v_S) = v_S - p_S$. The corresponding app demand n_U is $n_U = 1 - \frac{p_S}{V_S}$.

We take advertisers to be heterogeneous in their valuation for advertising v_A, which represents the value the advertiser can obtain through publishing his ad. Assume v_A is uniformly distributed on $[0, V_A]$, then consistent with prior literature (Rochet & Tirole 2006), the profit function for advertiser v_A, indexed by his ad i, is:

$$\pi_A(v_A) = \rho_i(v_A - p_A)n_U,$$

where n_U is the number of app users and p_A is the ad price. An advertiser would participate if and only if $\pi_A(v_A) \geq 0$. Thus the ad demand n_A is:

$$n_A = m\Pr(\pi_A(v_A) \geq 0) = m\left(1 - \frac{p_A}{V_A}\right)$$

It is worthwhile noting that the advertiser's advertising value v_A and the ad price p_A in our model can be considered as per-impression advertiser value and per-impression advertiser charge respectively, which accords well with traditional advertising literature (Athey and Gans 2010) as well as with real world practice as seen with iAd.

We can now determine that when the app developer chooses to publish advertising, the channel owner's profit is:

$$\pi_C = p_S r_S n_U + \beta p_A r_A n_U n_A,$$

and the app developer's is:

$$\pi_D = p_S(1 - r_S)n_U + \beta p_A(1 - r_A)n_U n_A.$$

In the absence of advertising, with $n_A = 0$, the profit functions are simplified to $\pi_C = p_S r_S n_U$ for the channel owner and $\pi_D = p_S(1 - r_S)n_U$ for the app developer.

The timing of the game is as follows. In stage 1, the channel owner announces p_A and r_A. In stage 2, the app developer decides whether to be a publisher and announces p_S. In stage 3, the app users decide whether to purchase the app and advertisers decide whether to participate. The channel owner's revenue share for app sales r_S is treated as exogenously given, because our study focuses on how the channel owner optimally engages the app developer in publishing ads, given that the app developer is already selling the app. The choice of r_S is closely related to the app developer's participation decision to join the platform, which is beyond the scope of this paper. All notation is summarized in Table 1.

Table 1: Summary of Notation

	Decision Variables
$\boldsymbol{p_S}$	App price
$\boldsymbol{p_A}$	Ad price
$\boldsymbol{r_A}$	Proportion the channel owner extracts from ad revenue (channel owner's ad revenue share in short)
	Other Variables
$\boldsymbol{n_U}$	App demand (number of participating app users)
$\boldsymbol{n_A}$	Ad demand (number of participating advertisers)
$\boldsymbol{\eta}$	Fill rate
$\boldsymbol{u}$	App users' utility
$\boldsymbol{\pi_C}$	Channel owner's profit
$\boldsymbol{\pi_D}$	App developer's profit
$\boldsymbol{\pi_A}$	Advertiser's profit
	Parameters
$\boldsymbol{r_S}$	Proportion the channel owner extracts from app sales revenue (i.e,, the channel owner's app revenue share)
$\boldsymbol{\gamma}$	Nuisance cost when the ad space in the app is filled with ads
$\boldsymbol{\beta}$	Slope parameter in the linear approximation for fill rate
$\boldsymbol{\rho_i}$	Probability ad i is displayed
$\boldsymbol{v_S}$	An app user's valuation for the app
$\boldsymbol{v_A}$	An advertiser's valuation for advertising
$\boldsymbol{V_S}$	Maximum user's valuation for the app (app value in short)
$\boldsymbol{V_A}$	Maximum advertiser's valuation for advertising (ad value in short)
$\boldsymbol{m}$	The size of the advertising market

App Developer's Strategy

In response to the channel owner's decisions on ad price p_A and the channel owner's ad revenue share r_A, the app developer makes his publishing decision as well as his pricing decision for the app p_S. Proposition 1 summarizes the optimal choices for the app developer. We assume that $\frac{V_S}{2} - \gamma \geq 0$, or equivalently, $V_S \geq 2\gamma$. This is a conservative assumption which ensures positive sales for the app with the mean app value of $\frac{V_S}{2}$ when the app is offered for free and its ad space is filled.

Proposition 1 (App Developer's Strategy): *Given the channel owner's decisions on ad price p_A and channel owner's ad revenue share r_A, the app developer will*

a. *(pure app) become a pure app seller, i.e., decline to publish ads, and charge a positive price for the app, setting $p_S = \frac{V_S}{2}$, if $1 - \frac{\gamma(1-r_S)}{p_A} < r_A \leq 1$;*

b. *(hybrid) become an advertising publisher and charge a positive price for the app, setting $p_S = \frac{V_S}{2} - \frac{\beta m(V_A - p_A)[p_A(1-r_A)+\gamma(1-r_S)]}{2V_A(1-r_S)}$, if $1 + \frac{\gamma(1-r_S)}{p_A} - \frac{V_A V_S(1-r_S)}{\beta m p_A(V_A-p_A)} < r_A \leq 1 - \frac{\gamma(1-r_S)}{p_A}$;*

   or

c. *(pure ad) become an advertising publisher and offer the app for free, setting $p_S = 0$, if $0 \leq r_A \leq 1 + \frac{\gamma(1-r_S)}{p_A} - \frac{V_A V_S(1-r_S)}{\beta m p_A(V_A-p_A)}$.*

The regions corresponding to case a, b and c above are illustrated in Figure 2. Detailed proof of Proposition 1 is provided in Appendix A.

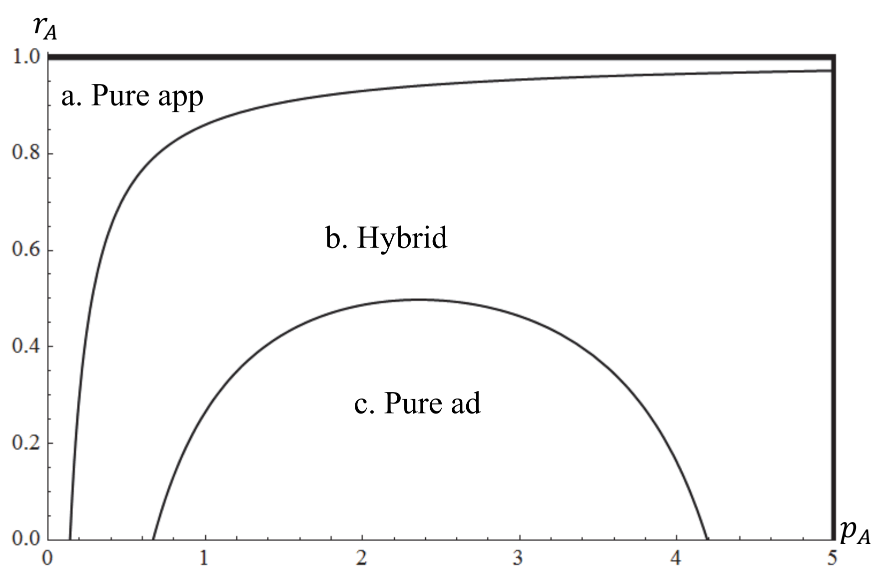


Figure 2: App Developer's Strategy

Notes: Figure 2 is generated based on $r_S = 0.3$, $V_S = 1$, $V_A = 5$, $\gamma = 0.2$, $\beta = 1$, and $m = 1$. Bold lines indicate the feasible range of p_A and r_A, i.e., $0 \leq p_A \leq V_A$ and $0 \leq r_A \leq 1$.

Figure 2 provides an illustrative example of the app developer's optimal strategies. The app developer can choose (a) to remain a pure app seller (not publish ads), (b) to publish ads and sell the app at a positive price or (c) to publish ads and offer the app for free. In region a, where the ad price p_A is low, the channel owner's ad revenue share r_A is high, or both, the app developer simply avoids publishing ads and focuses on selling the app. This is because low p_A, high r_A, or a combination of both limits the app developer's per ad revenue $p_A(1-r_A)$ and thus the developer has insufficient incentive to publish ads.

When the app developer's per ad revenue $p_A(1-r_A)$ is higher than a threshold (in region b), the app developer chooses to publish ads, but will rely on a combination of advertising and app sales revenue for profits. Proposition 1 shows that the app price in region b is less than that in region a, which indicates that the app developer will reduce the app price if it switches from the pure app strategy to the hybrid strategy. There are two reasons for this: First, when ads are published in the app, app users experience a nuisance cost which the app developer accounts for by reducing the price. Second, after becoming a publisher, the developer gains an additional revenue source from the advertising channel in the amount of $\beta p_A(1-r_A)n_U n_A$. Since reducing the app price p_S helps increase the app demand n_U, which in turn increases the revenue from the advertising channel, the app developer has additional incentive to reduce the app price.

When the channel owner's ad revenue share r_A is low, and the advertising price p_A is moderate (region c), the app developer gives away the app for free and focuses entirely on ad revenue to take advantage of generous ad revenue sharing (low r_A). However, it is interesting to note that as the ad price p_A increases beyond a certain level (the part of region b to the right of region c), even with the most generous ad revenue sharing ($r_A = 0$) the app developer again charges a positive price for the app. This is because ad demand n_A is greatly reduced at a high ad price p_A. Although app demand n_U increases because of a reduced nuisance cost $\gamma\beta n_A$, the app developer's revenue from publishing ads $\beta p_A(1-r_A)n_U n_A$ greatly diminishes due to small n_A. Therefore, the app developer will no longer rely only on publishing ads but chooses to again profit from selling the app.

CHANNEL OWNER'S STRATEGY

Anticipating the other players' responses, the channel owner decides the ad price p_A and the channel owner's ad revenue share r_A to maximize her profit. Proposition 2 summarizes the equilibrium strategy for the channel owner.

Proposition 2 (Channel Owner's Strategy): *Depending on the market conditions, the channel owner adopts one of the following four sets of ad price p_A and owner's ad revenue share r_A in equilibrium:*

a. (pure app) If $V_A \le \gamma$, then

set p_A and r_A to satisfy $1-\frac{\gamma(1-r_S)}{p_A} \le r_A \le 1$;

b1.(app-oriented hybrid) If $V_S \ge \frac{\beta m(V_A-\gamma)^2}{4V_A(1-r_S)}$ *and* $V_A \ge \gamma$, *then*

$p_A = \frac{V_A+\gamma}{2}$ *and* $r_A = 1-\frac{2\gamma(1-r_S)}{V_A+\gamma}$;

b2.(ad-oriented hybrid) If $\frac{\beta m(V_A-\gamma)[V_A+\gamma(7-4r_S)]}{4V_A(3-2r_S)} \le V_S \le \frac{\beta m(V_A-\gamma)^2}{4V_A(1-r_S)}$, *then*

$p_A = \frac{V_A+\gamma}{2}$ *and* $r_A = \frac{2\gamma r_S}{V_A+\gamma} + \frac{V_A-\gamma}{(2-r_S)(V_A+\gamma)} + \frac{4V_A V_S(1-r_S)^2}{\beta m(2-r_S)(V_A-\gamma)(V_A+\gamma)}$; *or*

c. (pure ad) If $2\gamma\beta m \le V_S \le \frac{\beta m(V_A-\gamma)[V_A+\gamma(7-4r_S)]}{4V_A(3-2r_S)}$, *then*

$p_A = \frac{2V_A-\gamma(1-r_S)}{3} - \frac{V_A V_S+\sqrt{(V_A V_S-2\gamma\beta m V_A-\beta m\gamma^2(1-r_S))^2+3\gamma\beta m V_A(V_S-\gamma\beta m)(V_A-2\gamma(1-r_S))}}{3\gamma\beta m}$ *and*

$r_A = 1+\frac{\gamma(1-r_S)}{p_A} - \frac{V_A V_S(1-r_S)}{\beta m p_A(V_A-p_A)}$.

The regions corresponding to case a, b1, b2, and c above are illustrated in Figure 3. Detailed proof of Proposition 2 is provided in Appendix B.

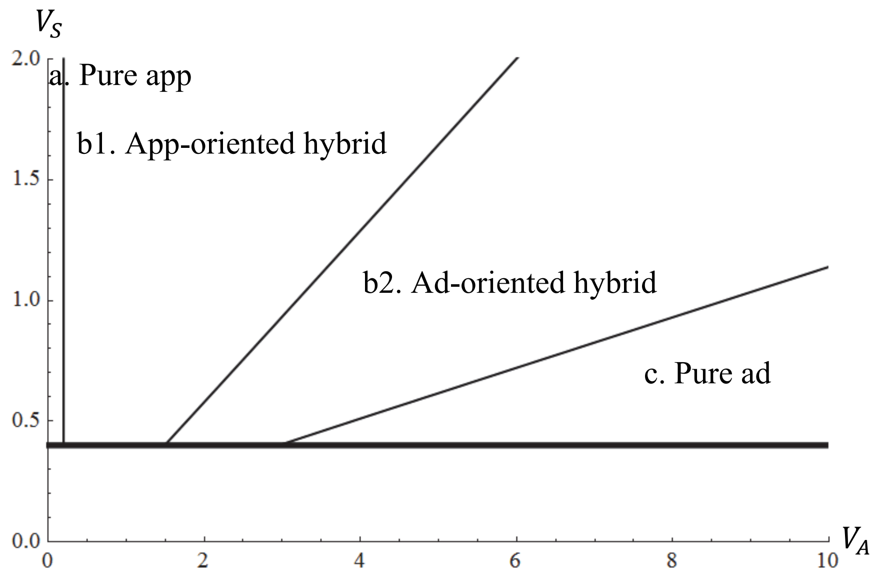


Figure 3: Channel Owner's Strategy

Notes: Figure 3 is generated based on $r_S = 0.3$, $\gamma = 0.2$, $\beta = 1$, and $m = 1$. The bold line indicates the boundary line of our assumption, i.e., $V_S \geq 2\gamma$.

Proposition 2 presents the channel owner's equilibrium choices of the ad price p_A and her ad revenue share r_A. For ease of exposition, we add superscripts to the variables in Table 1 to represent the equilibrium values of those variables in the corresponding cases in Proposition 2. For example, π_C^{b2} represents the channel owner's equilibrium profit in case b2. In Figure 3, we provide an illustrative example of the equilibrium strategies for the channel owner under different parameters of ad value V_A and app value V_S. In the pure app region (a in Figure 3), the ad value V_A is less than the nuisance cost γ, and the channel owner sets p_A and r_A such that the app developer declines to publish advertising. Thus only app sales happen in this case, and the equilibrium app price is set to the monopoly app price $p_S^a = \frac{V_S}{2}$.

In both cases b1 and b2, the channel owner sets the ad price p_A and her ad revenue share r_A to induce the app developer to both set a positive app price ($p_S^{b1} > 0$ and $p_S^{b2} > 0$) and publish advertising. In these cases the revenue of the channel owner and the app developer comes from both app sales and ad publication. Therefore we call regions b1 and b2 hybrid regions, with b1 being the app-oriented hybrid region (hereafter app-oriented region) and b2 the ad-oriented hybrid region (hereafter ad-oriented region). In case c, the pure ad region, the channel owner maximizes its profit by inducing the app developer to give away the app for free ($p_S^c = 0$), and to concentrate on advertising revenue alone.

Next we analyze the underlying factors that drive the formation of those regions. We begin by analyzing the equilibrium prices and demands of the two sides of the market.

Proposition 3 (App Price, Ad Price, App Demand, and Ad Demand): *In equilibrium, the app price p_S, the ad price p_A, the app demand n_U, and the ad demand n_A have the following properties:*

- *the equilibrium app prices under different regions are:* $p_S^a = \frac{V_S}{2} > 0$, $p_S^{b1} = \frac{V_S}{2} - \frac{\gamma\beta m(V_A-\gamma)}{2V_A} > 0$, $p_S^{b2} = \frac{V_S(3-2r_S)}{2(2-r_S)} - \frac{\beta m(V_A-\gamma)(V_A+7\gamma-4\gamma r_S)}{8V_A(2-r_S)} > 0$, *and* $p_S^c = 0$.
- *the equilibrium app price in the app-oriented region* p_S^{b1} *is lower than that in the pure-app region* p_S^a, *i.e.,* $p_S^a = \frac{V_S}{2} > p_S^{b1} = \frac{V_S}{2} - \frac{\gamma\beta m(V_A-\gamma)}{2V_A} > 0$.
- *the equilibrium ad price increases in ad value* V_A, *i.e.,* $\frac{\partial p_A^{b1}}{\partial V_A} > 0$, $\frac{\partial p_A^{b2}}{\partial V_A} > 0$, *and* $\frac{\partial p_A^c}{\partial V_A} > 0$.

- *the app demand n_U increases in ad value V_A in the ad-oriented region and the pure-ad region and is not affected by V_A in other regions, i.e.,* $\frac{\partial n_U^{b2}}{\partial V_A} > 0$, $\frac{\partial n_U^{c}}{\partial V_A} > 0$, *and* $\frac{\partial n_U^{a}}{\partial V_A} = \frac{\partial n_U^{b1}}{\partial V_A} = 0$.
- *the ad demand n_A increases in ad value V_A in the app-oriented region and the ad-oriented region, i.e.,* $\frac{\partial n_A^{b1}}{\partial V_A} > 0$, $\frac{\partial n_A^{b2}}{\partial V_A} > 0$, *but decreases in ad value V_A in the pure ad region, i.e.,* $\frac{\partial n_A^{c}}{\partial V_A} < 0$.

Detailed proof of Proposition 3 is provided in Appendix C.

As shown in Proposition 3 and Figure 4, the optimal ad price p_A increases in ad value V_A in all regions. This means that when advertisers are able to generate higher value from reaching app users through ads (higher V_A), the channel owner should also charge a higher ad price p_A to take advantage of such improvements.

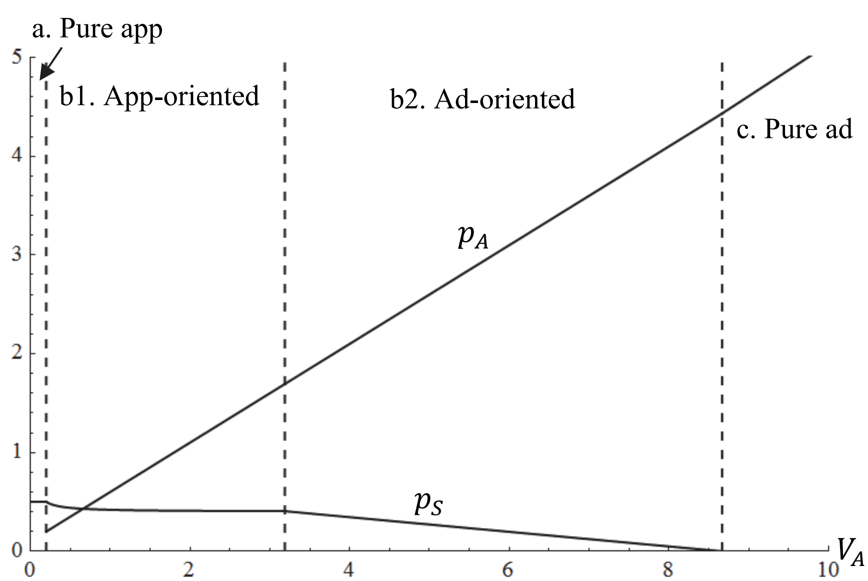


Figure 4: App Price and Ad Price

Notes: Figure 4 is generated based on $r_S = 0.3$, $V_S = 1$, $\gamma = 0.2$, $\beta = 1$, and $m = 1$. In the pure app region, p_A is not applicable.

Proposition 3 also shows that the equilibrium number of participating advertisers n_A increases in ad value V_A in the app-oriented region and the ad-oriented region (as shown in Figure 5), since the channel owner considers not only that it is optimal to charge a higher ad price p_A to take advantage of the higher ad value V_A, but also sets ad price p_A to induce a higher number of the advertisers to join the market.

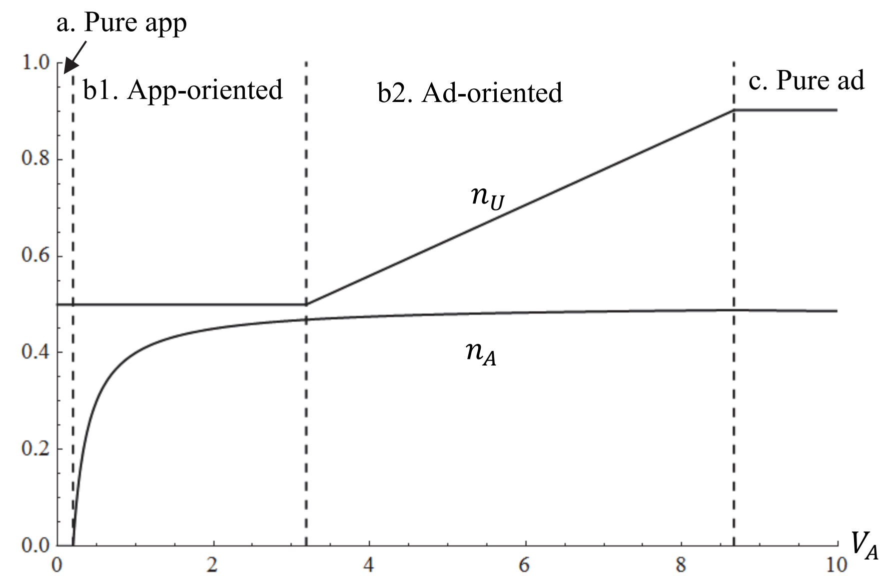


Figure 5: App Demand and Ad Demand

Notes: Figure 5 is generated based on $r_S = 0.3$, $V_S = 1$, $\gamma = 0.2$, $\beta = 1$, and $m = 1$.

When more advertisers join the market, app users will incur a higher nuisance cost. The fact that the equilibrium number of participating advertisers n_A increases for the channel owner as ad value V_A increases across both the app-oriented region and the ad-oriented region, implies that the channel owner seeks to shift the profit-making segment to the advertiser side of the market. As shown in Figure 6, the channel owner's profit from app sales decreases in ad value V_A while its profit from advertising increases in V_A. Traditional two-sided market literature has shown that when more value can be extracted from one side of the market, the single-entity platform (which has direct control over the prices of both sides of the market) will switch its profit-making segment to that side and subsidize the other side. This is known as the platform's *cross-side subsidization* (or simply *cross subsidization*) strategy (Jullien 2005; Rochet and Tirole 2006).

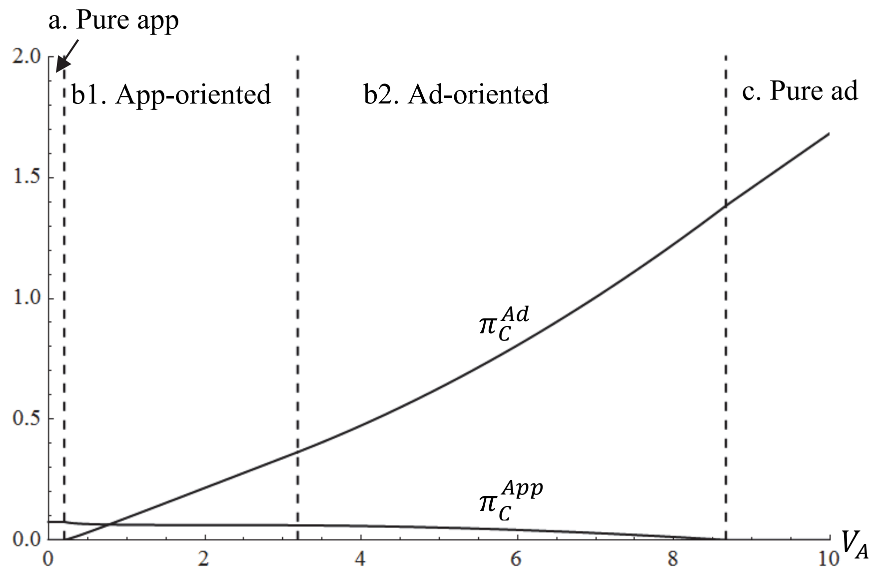


Figure 6: Channel owner's profit from app sales π_C^{App} and profit from advertising π_C^{Ad}

Notes: Figure 6 is generated based on $r_S = 0.3$, $V_S = 1$, $\gamma = 0.2$, $\beta = 1$, and $m = 1$.

We show that under the joint structure of the platform the switch of the profit-making segment also occurs, though the channel owner only has control over the price on the advertiser side of the market and thus is not able to directly subsidize the app user side of the market. From Figure 4 we can see that the app developer reduces the app price p_S when the ad value V_A increases beyond the nuisance cost γ, which indicates that the app user side of the market is subsidized by the app developer. From the developer's perspective, although decreasing the app price p_S will reduce revenues from app purchases, this loss will be justified by additional ad revenue generated from a greater number of app users. This demonstrates that *cross-side* *subsidization,* which in traditional literature requires the platform to have direct control over the prices on both sides of the market, can also be completed jointly by the channel owner and the app developer, each controlling only one side of the market. We next turn our attention to the dynamics within the platform, i.e., between the channel owner and the app developer.

Proposition 4 (App Developer's Profit): *Comparing the app developer's profit in different regions, we find that:*

- *given the app value V_S, the app developer's profit in the app-oriented region π_D^{b1} is equal to that under the pure-app region, i.e., $\pi_D^a = \pi_D^{b1} = \frac{(1-r_S)V_S}{4}$, which is not affected by the ad value V_A.*
- *the app developer's profit in the ad-oriented region π_D^{b2} increases in the ad value V_A, i.e., $\frac{\partial \pi_D^{b2}}{\partial V_A} > 0$.*

Detailed proof of Proposition 4 is provided in Appendix D.

As we have seen, when the ad value V_A exceeds the nuisance cost γ, the market equilibrium will initially reside in the app-oriented region. Proposition 4 shows that in the app-oriented region, although the app developer starts to gain revenue from the advertising channel, his total profit remains the same as the pure app sale region. For the advertising channel to open, the channel owner chooses optimal ad price p_A, and needs only set her ad revenue share r_A to just provide minimal additional revenue to the app developer beyond pure app sale revenues. The rest of the revenue generated from the advertising channel can be withheld by the channel owner. We can clearly see in Figure 7 that as the ad value V_A increases in the app-oriented region, the channel owner's profit increases while the app developer's remains the same.

This result helps explain why the app developer may be initially disappointed by flat revenues even when publishing ads. As the ad value V_A improves from the pure app region to the app-oriented region, the channel owner is able to extract virtually all the gains of advertising above the amount needed by the app developer to become a publisher. The app developer cannot benefit from the initial augmentation in ad value V_A, and thus cannot benefit from the initial growth of the advertising market.

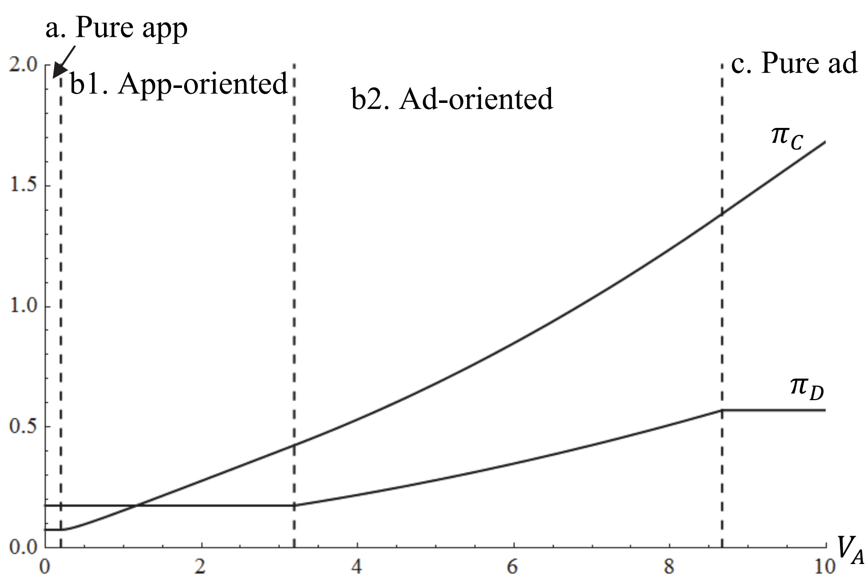


Figure 7: Profits of the channel owner and the app developer

Notes: Figure 7 is generated based on $r_S = 0.3$, $V_S = 1$, $\gamma = 0.2$, $\beta = 1$, and $m = 1$.

However, as the ad value V_A continues to increase into the ad-oriented region, the app developer's profit starts to increase in ad value V_A (Figure 7). The app developer in the ad-oriented region now can benefit from the growth of the advertising market. What drives these contrasting outcomes in the app-oriented versus the ad-oriented regions? We can see from Proposition 2 that the equilibrium ad price p_A remains the same for these two regions. However, the channel owner's ad revenue sharing strategy r_A shifts significantly when switching from app-oriented region to the ad-oriented region.

To discern this channel owner's strategy shift and unpack her strategies in each region, we examine her ad revenue sharing strategy in Proposition 5.

Proposition 5 (Ad Revenue Sharing): *The channel owner's ad revenue share r_A has the following properties:*

- *r_A increases in the app-oriented region, i.e., $\frac{\partial r_A^{b1}}{\partial V_A} > 0$;*
- *r_A decreases in the ad-oriented region, i.e., $\frac{\partial r_A^{b2}}{\partial V_A} < 0$;*
- *r_A increases again in the pure ad region, i.e., $\frac{\partial r_A^{c}}{\partial V_A} > 0$.*

Detailed proof of Proposition 5 is provided in Appendix E.

Proposition 5 reveals an interesting advertising revenue sharing strategy for the channel owner. As shown in Figure 8, the equilibrium owner's ad revenue share r_A changes as the ad value V_A increases, increasing in the app-oriented region, then decreasing in the ad-oriented region, and then increasing again in the pure ad region.

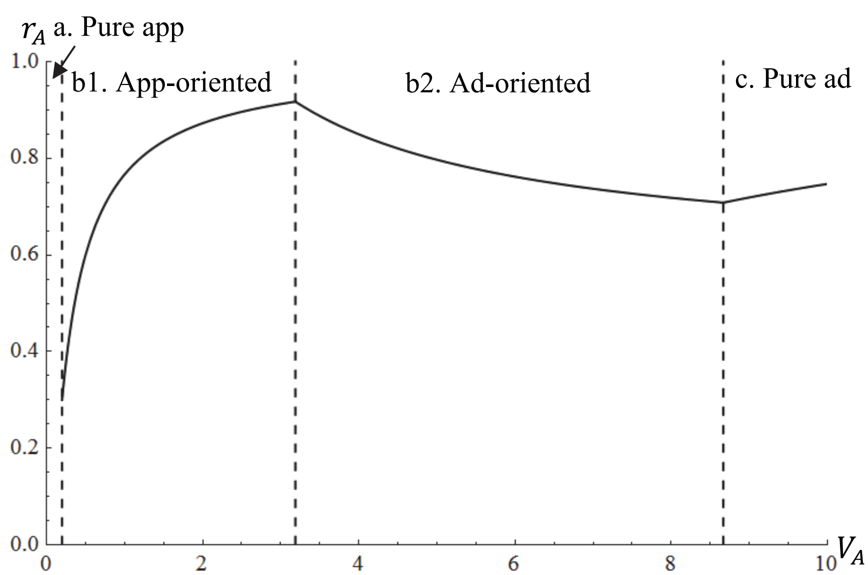


Figure 8: Channel Owner's Ad Revenue Share r_A

Note: Figure 8 is based on $r_S = 0.3$, $V_S = 1$, $\gamma = 0.2$, $\beta = 1$, and $m = 1$. In the pure app region, r_A is not applicable.

When the ad value V_A is relatively low and increases in the app-oriented region, the reduction in app price p_S^{b1} due to cross-side subsidization (Figure 4) is driven purely by the app developer. The increased advertising revenue resulting from cross-side subsidization will be retained by the channel owner by increasing her ad revenue share r_A, leaving only the minimal per ad revenue $p_A(1 - r_A)$ required for the app developer to engage in publishing ads. However, when V_A is relatively high in the ad-oriented region, the channel owner will start to increase the developer's per ad revenue $p_A(1 - r_A)$ by decreasing her ad revenue share r_A in order to induce a lower p_S. This increased per ad revenue provides further incentive for the app developer to reduce app price p_S^{b2} at a faster rate with respect to V_A, as shown in Figure 4.We introduce the term *between-agent subsidization* to characterize this phenomenon. Here the channel owner subsidizes the app developer in the advertising channel, to further bring down the app price. The resulting increase in the number of app users makes the advertising channel more profitable, and the profit-making segment moves further to the advertiser side, benefitting both the channel owner and the app developer.

The interesting dynamics of channel owner's ad revenue share r_A emerge because two underlying forces compete with each other to drive r_A in opposite directions. On the one hand, the channel owner can increase r_A to gain a larger share of total ad revenue. On the other hand, the channel owner can decrease r_A to subsidize the app developer with more ad revenue in order to reduce the app price p_S. Such a reduction in app price will enlarge the number of app users and reduce the app sale revenue. This between-agent subsidization of the app developer by the channel owner in the advertising channel, i.e. decreasing r_A, is effective when ad value V_A is sufficient to assure that the app developer's marginal benefit of an additional app user in ad revenues exceeds the loss from reduced app sale revenue in the app sales channel. Of these two forces, the channel owner's desire to increase r_A is consistent once the developer chooses to become a publisher, but the strength of the force that drives r_A down varies under different ad value V_A.

In the app-oriented region b1, the ad value V_A is relatively low, there are relatively few advertisers participating, so the marginal benefit of one additional app user in ad revenues is low. The channel owner won't find it profitable to reduce her ad revenue share r_A to induce a lower app price because it doesn't justify the corresponding loss of app revenue. Therefore, the between-agent subsidization strategy is not feasible. Hence the channel owner increases r_A in V_A, maintaining just enough incentive for the app developer to become a publisher. In the ad-oriented region b2, the ad value V_A is relatively high and the dynamics reverse, with sufficient advertisers to justify the between-agent subsidization strategy. The channel owner is willing to reduce r_A because the marginal benefit of an additional app user in ad revenues is greater than the corresponding cost to bring that user in.

When the ad value V_A further increases to the pure ad region c, the app price has already been reduced to 0 and the channel owner does not need to provide any further incentive to the app developer to reduce the app price p_S, so her ad revenue share r_A starts to increase again. The channel owner drops the between-agent subsidization used in the ad-oriented region b2 with a subtle difference in motivation: in the app-oriented region b1 she doesn't want to subsidize the app developer, while in pure ads region c, she doesn't need to.

The fact that the app developer owns the pricing right for app sales is one direct reason for the channel owner's between-agent subsidization strategy in the ad-oriented region. In the ad-oriented region, the channel owner subsidizes the app developer by providing an increase share of ad revenue (Figure 8) in order to induce the app developer to set a lower app price p_S. It is the app developer's pricing right in the app sales channel that guarantees this ad channel subsidy, and thus that the app developer's total profit can grow substantially as the advertising market grows (in the ad-oriented region b2 in Figure 7). Thus the app developer's pricing right for app sales not only gives the app developer market power in the app sales channel, but also benefits him in the advertising channel.

COORDINATION WITHIN THE PLATFORM

As we mentioned in the introduction, the issue of coordination arises because the channel owner and the app developer are independent, yet they jointly create the advertising channel according to an advertising contract. Following the standard procedure for studying the coordination issue (Cachon and Lariviere 2005), we derive the platform optimal actions that maximize the platform profit, i.e., the aggregate profit of the channel owner and the app developer, and then contrast them with the equilibrium results.

Proposition 6 (Platform Optimum): *Depending on market conditions, the platform optimal ad price p_A and app price p_S are as follows:*

a. (pure app) If $V_A \leq \gamma$, then $p_A \geq V_A$ and $p_S = \frac{V_S}{2}$;

b. (hybrid) If $V_S \geq \frac{\beta m(V_A-\gamma)(V_A+3\gamma)}{4V_A}$ and $V_A \geq \gamma$, then $p_A = \frac{V_A+\gamma}{2}$ and

$$p_S = \frac{4V_AV_S-\beta m(V_A-\gamma)(V_A+3\gamma)}{8V_A};$$

c. (pure ad) If $V_S \leq \frac{\beta m(V_A-\gamma)(V_A+3\gamma)}{4V_A}$, then $p_A = \frac{V_A\left(2\gamma\beta m-V_S+\sqrt{V_S^2-\gamma\beta m V_S+\gamma^2\beta^2m^2}\right)}{3\gamma\beta m}$ and $p_S = 0$.

The regions corresponding to case a, b, and c above are illustrated in Figure 9. Detailed proof of Proposition 6 is provided in Appendix F.

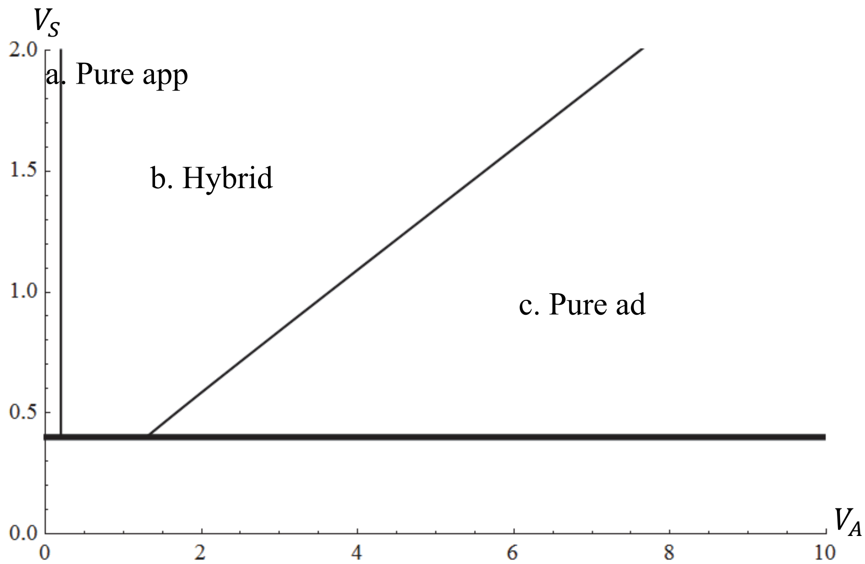


Figure 9: Platform Optimum

Notes: Figure 9 is generated based on $r_S = 0.3$, $\gamma = 0.2$, $\beta = 1$, and $m = 1$.

Proposition 6 shows that three regions emerge in the platform optimum: the pure app region, the hybrid region and the pure ad region, though in this case the hybrid region does not split into two distinct parts as it did in the earlier equilibrium results. The boundaries of those regions of the platform optimum in terms of ad value V_A are also different from the boundaries in the equilibrium. The results demonstrate that the in general the equilibrium outcomes don't coincide with the platform optimum, indicating a failure of coordination for the advertising revenue sharing contract. We next compare the equilibrium prices to the platform optimum prices to further demonstrate this coordination failure.

Proposition 7 (Comparing the Equilibrium Prices to the Platform Optimum): *Comparing the equilibrium ad price p_A^{Eqm} and app price p_S^{Eqm} to the platform optimal prices p_A^{Platform} and p_S^{Platform}, we find that:*

a. If $V_A \leq \gamma$, then $p_S^{\text{Eqm}} = p_S^{\text{Platform}}$; If $V_A > \gamma$, then $p_S^{\text{Eqm}} > p_S^{\text{Platform}}$;

b. If $V_S \geq \frac{\beta m(V_A-\gamma)(V_A+3\gamma)}{4V_A}$*, then* $p_A^{\text{Eqm}} = p_A^{\text{Platform}}$*; If* $V_S \leq \frac{\beta m(V_A-\gamma)(V_A+3\gamma)}{4V_A}$*, then* $p_A^{\text{Eqm}} <$ p_A^{Platform}.

Detailed proof of Proposition 7 is provided in Appendix G.

Proposition 7 and Figure 10 show that the equilibrium app price p_S^{Eqm} is consistently higher than the platform optimal app price p_S^{Platform} for all ad values V_A greater than the nuisance cost γ. When the platform optimal app price p_S^{Platform} becomes zero, the equilibrium ad price p_A^{Eqm} is consistently lower than the platform optimal ad price p_A^{Platform}. Therefore, we conclude that the advertising revenue sharing contract fails to coordinate the advertising platform under agency pricing for app sales as long as the ad value V_A is sufficient to justify publishing ads.

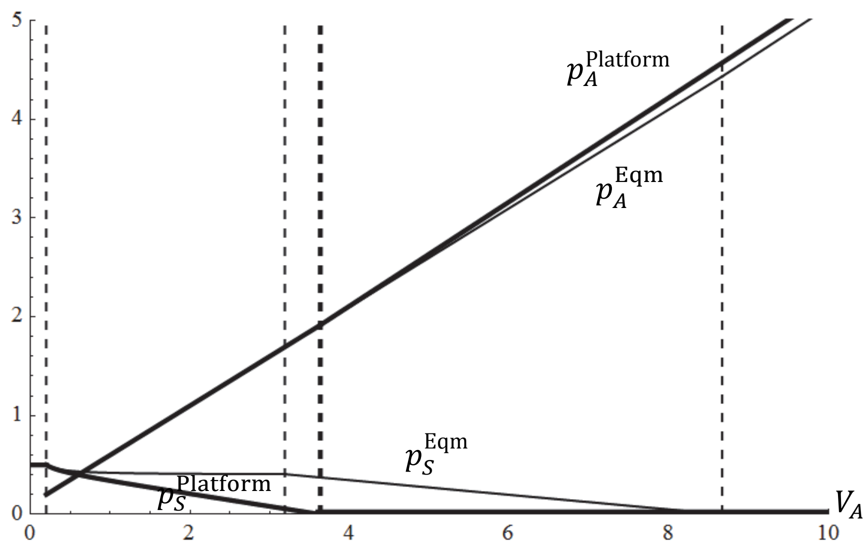


Figure 10: Comparing the Equilibrium Prices to the Platform Optimum

Notes: Figure 10 is generated based on $r_S = 0.3$, $V_S = 1$, $\gamma = 0.2$, $\beta = 1$, and $m = 1$. In the pure app region, p_A is not applicable. Regular lines correspond to the equilibrium prices and bold lines correspond to the platform optimum.

Agency pricing for app sales plays a key role in explaining why the equilibrium app price p_S^{Eqm} is consistently higher than the platform optimal app price p_S^{Platform}. Under agency pricing for app sales, the app developer has the right to determine the app price and the channel owner has the right to determine her margin on ad sales through p_A and r_A. The consumption of the app and the ads is controlled by the app developer and the channel owner jointly. Thus, two types of externalities emerge: first, the app price chosen by the app developer has a direct impact on the channel owner's app sales revenue; second, the app price chosen by the app developer also affects the app user base and thus has an indirect impact on the channel owner's advertising revenue.

When making the pricing decision for the app, the app developer does not take into account its impact on the channel owner's profit. Such externalities cannot be internalized when the channel owner chooses her ad revenue share r_A because of a misalignment between the objective of coordinating the platform, i.e., attaining the maximum aggregate profit of the platform, and the objective of maximizing the channel owner's profit. More specifically, the objective of coordinating the platform drives the channel owner's ad revenue share r_A down in order to bring down the app price, but the objective of maximizing her profit drives r_A up. Therefore in equilibrium r_A is at a level that is higher than the level that coordinates the platform, and this leads to an equilibrium app price p_S^{Eqm} greater than the platform optimal app price p_S^{Platform}. Consequently, consumers are hurt due to the coordination failure, paying a higher price for the app than would be the case with a coordinated platform.

DISCUSSION AND CONCLUSIONS

In this paper, we develop a two-sided market model that extends a traditional advertising model to capture the unique characteristics of the mobile advertising market. Specifically we incorporate two entities in the platform – the channel owner and the app developer – coordinated by an agency pricing agreement that allows the app developer to set the app selling price, and an advertising contract in which the channel owner determines the advertising price for advertisers and the channel owner's and app developer's respective shares of advertising revenue. Using this approach, we are able to answer several questions concerning the emerging market for mobile advertising.

We find that it is optimal and feasible for the channel owner to induce the app developer to publish ads when ad values are sufficiently high to overcome the nuisance cost to app users of displayed ads. Under agency pricing for app sales, the channel owner may engage in a *between-agent subsidization* strategy. As the ad value V_A increases, the channel owner may reduce its own share for advertising revenue r_A to provide extra incentive for the app developer to reduce the app price. In 2012, Apple increased the developer's iAd revenue share from 60% to 70% (Aimonetti 2012). This paper may provide a potential explanation for this change: the channel owner may increase the app developer's ad revenue share as an effort to shift the focus to the advertising channel and eventually obtain higher overall profit. This between-agent subsidization strategy is unique to the mobile advertising platform because the two entities, the channel owner and the app developer, jointly control ad provisioning, and the advertising revenue sharing contract serves as an instrument for the channel owner to manage the app developer's incentive for publishing ads.

We provide a detailed explanation of the mechanism for the differing strategies used by the channel owner as the value of advertising increases, first to induce the app developer to become a publisher, and let the developer reduce the app price on his own, which generates greater total profit for the channel owner only; and then, under certain market conditions, to subsidize the developer to further reduce the app price, which eventually leads to greater profits for both the channel owner and the developer. The dynamics in response to changing market conditions offer an explanation for the perception that app developers, when they begin to sell advertising, do not experience increased profits. Those dynamics also reveal the role of agency pricing in the channel owner's design of the advertising contract as, for example, with the between-agent subsidization strategy.

From the advertising platform perspective, we find that an advertising revenue sharing contract under agency pricing for app sales fails to coordinate the advertising platform when the channel owner determines the advertising revenue sharing percentage. Agency pricing, in which the channel owner delegates the app sale price decision to the developer, thus yielding market power on the app user side of the market, causes this coordination failure, leading to a higher app price.

Channel owners are known to attempt to improve the value of advertising by attempting to match the ad displayed in the app with app user characteristics obtained, for example, from user profile or geo-location data. While this is clearly an important topic in its own right, it is beyond the scope of this work, though the way we model the provision of ads may be amenable to extension to consider this issue in future work. Though we generate important insights for firm strategy for advertising in the mobile app space, there are some known strategies that are beyond the scope of this research. A versioning strategy used by some app developers is to offer a free version of the app with ads, and a paid ad-free version. This enables a segmentation of app users in terms of their heterogeneous nuisance cost due to in-app ads. In this paper, we consider consumers that differ in terms of their heterogeneous app value, in order to focus on the impact of the agency pricing in app sales channel on the channel owner's advertising contract. The analysis of this versioning strategy is beyond the scope of this paper and we leave it for future research.

References

Aimonetti, J. 2012. "Apple Increases Developer iAd Revenue to 70 Percent," *CNET*, April 2.

Anderson, S. P. and Gabszewicz, J. J. 2006. The Media and Advertising: A Tale of Two-Sided Markets, in *Handbook of the Economics of Art and Culture*, Oxford, UK: Elsevier B.V.

Anderson, S. P., Coate, S. 2005. "Market Provision of Broadcasting: A Welfare Analysis," *Review of Economic Studies* (72:4), pp. 947-972.

Apple Inc. 2013a. *"iOS Developer Program,"* Available at: https://developer.apple.com/programs/ios/distribute.html.

———. 2013b. *"iAd App Network Policy,"* Available at: https://developer.apple.com/support/appstore/iad-app-network/.

Arthur, C. 2013. "Apple Sells 50 Billionth App," *The Guardian*, May 16.

Asdemir, K., Kumar, N., and Jacob, V. S. 2012. "Pricing Models for Online Advertising: CPM Vs. CPC," *Information Systems Research* (23:3), pp. 804-822.

Athey, S., Gans, J. S. 2010. "The Impact of Targeting Technology on Advertising Markets and Media Competition," *American Economic Review* (100:2), pp. 608-613.

Bagwell, K. 2007. The Economic Analysis of Advertising, in *Handbook of Industrial Organization*, Oxford, UK: Elsevier B.V.

Cachon, G. P., Lariviere, M. A. 2005. "Supply Chain Coordination with Revenue-Sharing Contracts: Strengths and Limitations," *Management Science* (51:1), pp. 30-44.

Chen, J., Stallaert, J. 2012. "An Economic Analysis of Online Advertising using Behavioral Targeting," *Management Information Systems Quarterly*, Forthcoming.

Dellarocas, C. 2012. "Double Marginalization in Performance-Based Advertising: Implications and Solutions," *Management Science* (58:6), pp. 1178-1195.

eMarketer. 2012a. "US Mobile Ad Spending Soars Past Expectations," *eMarketer*, January 26.

———. 2012b. "US Mobile Ad Spending Jumps to $4 Billion," *eMarketer*, December 18.

Feng, J., Xie, J. 2012. "Performance-Based Advertising: Advertising as Signals of Product Quality," *Information Systems Research* (23:3), pp. 1030-1041.

Godes, D., Ofek, E., and Sarvary, M. 2009. "Content Vs. Advertising: The Impact of Competition on Media Firm Strategy," *Marketing Science* (28:1), pp. 20-35.

Hao, L., Fan, M. 2014. "An Analysis of Pricing Models in the Electronic Book Market," *MIS Quarterly*, Forthcoming.

Hu, Y., Shin, J., and Tang, Z. 2012. *"Performance-Based Pricing Models in Online Advertising: Cost Per Click Versus Cost Per Action,"* Working paper.

Jullien, B. 2005. "Two-Sided Markets and Electronic Intermediaries," *CESifo Economic Studies* (51:2-3), pp. 233-260.

Kumar, S., Sethi, S. P. 2009. "Dynamic Pricing and Advertising for Web Content Providers," *European Journal of Operational Research* (197:3), pp. 924-944.

Li, X., Gu, B., and Liu, H. 2013. "Price Dispersion and Loss Leader Pricing: Evidence from the Online Book Industry," *Management Science* (59:6), pp. 1290-1308.

Lin, M., Ke, X., and Whinston, A. B. 2012. "Vertical Differentiation and a Comparison of Online Advertising Models," *Journal of Management Information Systems* (29:1), pp. 195-236.

Liu, D., Kumar, S., and Mookerjee, V. S. 2012. "Advertising Strategies in Electronic Retailing: A Differential Games Approach," *Information Systems Research* (23:3), pp. 903-917.

Liu, D., Viswanathan, S. 2012. *"Information Asymmetry and Hybrid Advertising,"* Working paper.

Rochet, J., Tirole, J. 2006. "Two-Sided Markets: A Progress Report," *RAND Journal of Economics* (37:3), pp. 645-667.

Tan, Y., Mookerjee, V. S. 2005. "Allocating Spending between Advertising and Information Technology in Electronic Retailing," *Management Science* (51:9), pp. 1236-1249.

The Associated Press. 2011. "Apple App Store Hits 10 Billion Downloads," *The Associated Press*, January 22.

Trachtenberg, J. A. 2011. "E-Book Prices Prop Up Print Siblings," *The Wall Street Journal*, September 12.

Whitney, L. 2011. "Apple Remains King of App-Store Market," *CNET*, February 15.

Xu, L., Chen, J., and Whinston, A. B. 2012. "Effects of the Presence of Organic Listing in Search Advertising," *Information Systems Research* (23:4), pp. 1284-1302.

Xu, L., Chen, J., and Whinston, A. B. 2011. "Price Competition and Endogenous Valuation in Search Advertising," *Journal of Marketing Research* (48:3), pp. 566-586.

Zhang, X., Feng, J. 2011. "Cyclical Bid Adjustments in Search-Engine Advertising," *Management Science* (57:9), pp. 1703-1719.